Readers' Forum

Brief discussions of previous investigations in the aerospace sciences and technical comments on papers published in the AIAA Journal *are presented in this special department. Entries must be restricted to a maximum of 1000 words, or the equivalent of one* Journal *page including formulas and figures. A discussion will be published as quickly as possible after receipt of the manuscript. Neither the AIAA nor its editors are responsible for the opinions expressed by the correspondents. Authors will be invited to reply promptly.*

Comment on "Improved Method for the Measurement of Turbulence Quantities"

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THE authors[1] have to be commended for their efforts to improve the measurements of turbulence quantities without making any restrictive assumptions as to their relative magnitudes. The writers would like to discuss a number of points which are likely to prove vital in improving the results of the present method and in ensuring that proper comparisons are made with the results of others. It will also be indicated that there is a need to quantify the improvements achieved in an absolute sense so that the choice among the various methods of measuring turbulence quantities can be made without difficulty.

The experience of the writers shows that considerable care must be exercised in determining the sensitivity factor S of a hot-wire from the raw data. It appears that the authors have obtained this factor from a linearized response plot of E_L vs $U_{\rm eff}$. The response equation is squared and in the process S is also squared. A simple exercise was performed, to elucidate our point of contention, using the linearized anemometer voltage-velocity characteristics obtained by calibration in the potential core of a jet. The linearized output was analysed by two methods. First, from a plot of E_L vs $U_{\rm eff}$, S was obtained using a least square technique. This sensitivity factor was squared to get S^2. Let this value be S_l. The second method consisted of determining S^2 directly from a plot of E_L^2 vs $U_{\rm eff}^2$. This second value will be referred to as S_2. The ratio $(S_l - S_2)/S_l$ was found to be approximately 0.24, and the sum of the errors squared in E_L^2 was lower in the second method. In view of this, it is suggested that the second method be used to determine the sensitivity factor for the squared linearizer response in order to minimize the errors. This would improve the values of the mean and turbulent quantities deduced from the response equation.

The proposal of using a three-dimensional pitot probe to determine the mean velocities is not too encouraging from the point of view of the time factor and the limitations of the instrument at low speeds. Furthermore, the advantage obtained through the use of hot-wire is forfeited. In this regard, the writers would like to draw the attention of the authors to the work of Acrivlellis,[2] who has also used the squared response equation of the linearizer to determine the turbulent flowfield. The flowfield in Ref. 2 was determined without any recourse to pitot probe measurements.

It is felt that a more meaningful comparison would have been made had the authors also determined the flowfield in their jet by the conventional method. Since Rodi's results[3] are believed to be more reliable, it is only proper that the authors should have also compared their results with those of Rodi in Fig. 2. Rodi, even after eliminating room drafts, reported significant differences between his measurements of $\overline{v^2}$ and $\overline{uv}$ by conventional method and those of Ref. 4. He attributed the differences to the thermal wake interference of the x wires used by Wygnanski and Fiedler[4] and concluded that the results, obtained using a single hot-wire, are likely to be more reliable. The authors' results are also likely to be affected by the thermal wake problem. This should partly explain the remarkably good agreement with the results of Ref. 4. Rodi also showed that the conventional method underpredicts $\overline{uv}$. Therefore, the difference between Rodi's results for $\overline{uv}$ and those of the authors is expected to be larger. Perhaps a figure to show a similar comparison with Rodi's results of $\overline{v^2}$ and $\overline{uv}$ would help the readers.

It is felt that an independent and more reliable measurement of the turbulence field is required to compare the various methods, to decide without doubt that squaring improves the measurements without magnifying the errors, and to quantify the extent of the improvement. The present method appears to have the limitation that the higher order velocity correlations cannot be determined from the response equation developed.

Finally, it would help the readers if the authors would describe the method adopted to obtain the voltages and the values of K and G used in their method.

References

[1] Sampath, S., Ganesan, V., and Gowda, B.H.L., "Improved Method for the Measurement of Turbulence Quantities," *AIAA Journal*, Vol. 20, Jan. 1982, pp. 148-149.

[2] Acrivlellis, M., "Finding the Spatial Flow Field by Means of Hot-wire Anemometry," DISA Rept. No. 22, 1977, pp. 21-28.

[3] Rodi, W., "A New Method of Analyzing Hot-wire Signals in Highly Turbulent Flow, and its Evaluation in a Round Jet," DISA Rept. No. 17, 1977, pp. 9-18.

[4] Wygnanski, I. and Fiedler, F., "Some Measurements in the Self-Preserving Jet," *Journal of Fluid Mechanics*, Vol. 38, 1969, pp. 577-612.

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Reply by Authors to Swaminathan, Rankin, and Sridhar

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THE authors are grateful to the commenters for the various points they raised, and the following reply is offered.

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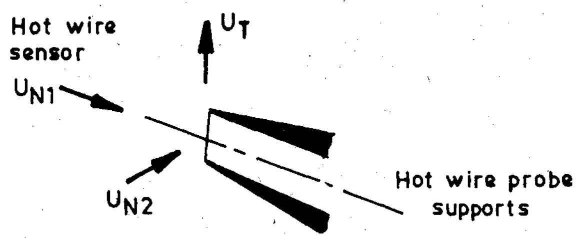

Fig. 1 Hot wire probe and velocity components.

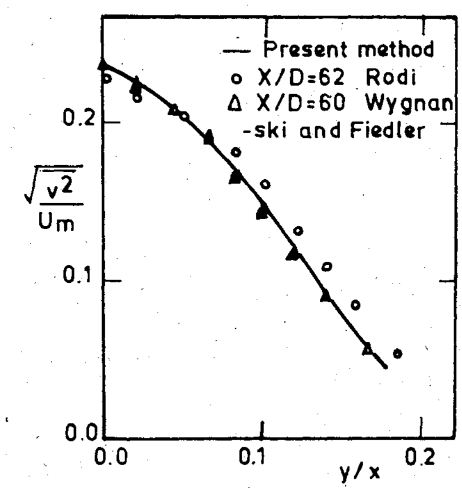

Fig. 2 $\sqrt{\overline{V^2}}/U_m$ distribution at $X=60\,D$.

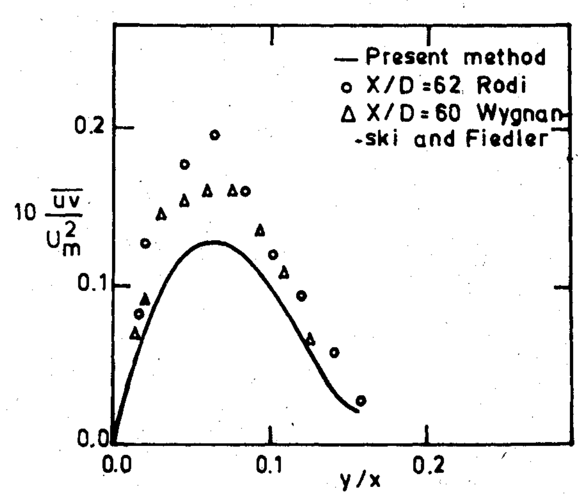

Fig. 3 Shear stress distribution at $X=60\,D$.

Regarding the determination of the sensitivity factor S for linearized operation, it was found only from the plot of E_L vs $U_{\rm eff}$. In the method suggested by Swaminathan et al., the voltage and corresponding velocity are measured initially and then squared to obtain the plot of E_L^2 vs $U_{\rm eff}^2$. Thus, the difference between S_1 and S_2 appears to come only from the plots. The method suggested by Swaminathan et al. for the determination of the factor S definitely can be incorporated, if found advantageous.

The present method was developed primarily with the aim of making measurements in three-dimensional recirculating flows. The use of a three-dimensional pitot probe is no doubt time consuming. However, its use in determining the direction of the mean velocity components in recirculating flows cannot be underestimated and, in many situations, there may not be other options. A reliable method for determining the direction of mean velocity components in such flows with a hot-wire is yet to be developed. In flows with no recirculation, either the straight wire or the inclined wire can be used to determine the mean velocity components, and the present method can be readily used.

Regarding the method proposed by Acrivlellis, the authors would like to draw the attention of Swaminathan et al. to the comments by Bartenwerfer[1] on the method. The final formulas (29-32) of Acrivlellis are not correct; hence the validity of the method to three-dimensional turbulent flows is doubtful.

Our measurements in free jets have been compared with the measurements of Wygnanski and Fiedler and with those of Rodi. The comparisons have not been presented in the paper because of space limitations. It was observed that while the measurements agreed well with those of Wygnanski and Fiedler, the results showed differences from the measurements of Rodi. This may be due to the interference between the two wires, as mentioned by Rodi. However, as suggested in our paper, interference can be avoided using two separate probes: one for the straight wire and another one for the inclined wire. But, this will increase the time of measurement and great care has to be exercised to make the measurements at the same point.

The directional sensitivity coefficient G and K of the wires have been determined from the calibration curves of the two wires[2] ($\bar{E}^2$ vs U_{N1}, $\bar{E}^2$ vs U_{N2}, and $\bar{E}^2$ vs U_T) using the relation

$$G=\frac{U_{N1}}{U_{N2}}, \quad K=\frac{U_{N1}}{U_T} \quad \text{at const } \bar{E}$$

where U_{N1}, U_{N2}, and U_T are the velocity components acting on the wire, as shown in Fig. 1. The average value of G was 1.18 for both wires and K was 0.09 for the straight wire and 0.2 for the inclined wire, over the range of velocities measured.

The comparison between Rodi's results and the present method are given in Figs. 2 and 3.

References

[1] Bartenwerfer, M., "Remarks on Hot-wire Anemometry Using Squared Signals," DISA Information No. 24, 1979, p. 4.

[2] Ganesan, V., "Recirculation and Turbulence Studies in an Isothermal Model of a Gas Turbine Combustion Chamber," Ph.D. Thesis, Dept. of Mechanical Engineering, Indian Institute of Technology, India, 1974.

Comment on "Inviscid Solution for the Secondary Flow in Curved Ducts"

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IN Ref. 1, Abdallah and Hamed calculated the inviscid, incompressible steady flow in curved ducts. They solve three equations for the three velocity components. In an Errata,[2] they give a different equation to replace one of the three in Ref. 1, which was given there erroneously due to a transcription error.

The purpose of this Comment is to point out that the equations they have solved are, in fact, the continuity

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